

# CHEMICAL SCIENCES

## DETERMINATION OF TOTAL PHOSPHORUS IN FOOD ADDITIVES FOR MEAT PRODUCTS

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### Abstract

The content of total phosphorus in terms of  $P_2O_5$  was determined in five samples of complex food additives with phosphates for meat products. A standardized spectrophotometric method for determining the mass fraction of total phosphorus was used, which involves mineralization of the sample, the reaction of phosphorus with ammonium monovanadate and ammonium heptamolybdate to form a yellow compound, and spectrophotometric measurement of optical density at a wavelength of 430 nm, and is used for meat and meat products. It was found that the content of total phosphorus in the objects of study varied from 3.0% to 57.0% and corresponded to that declared in the specifications for a specific food additive. A conclusion was made about the possibility of using the method used to control the mass fraction of total phosphorus in food additives with phosphates.

**Keywords:** meat products, complex food additives, phosphates, measurement method, spectrophotometry, mass concentration of total phosphorus

**Introduction.** Food additives used in the meat processing industry improve the appearance of meat products, their taste and other organoleptic indicators. One of the groups of food additives widely used in the meat industry are chemical compounds that increase the moisture-binding capacity of meat and meat products. They are used in cases where the moisture-binding capacity of meat is insufficient due to the high content of connective and fatty tissue, as well as after long-term storage of meat in a frozen state. These compounds are sodium and potassium salts of phosphoric acids (ortho- (mono-) phosphoric ( $H_3PO_4$ ); pyro- (di-) phosphoric ( $H_4P_2O_7$ ); triphosphoric ( $H_5P_3O_{10}$ ) and metaphosphoric ( $HPO_3$ )) and their mixtures, which are included in the recipes of curing brines for sausages and other meat products [1–4]. In addition to increasing the moisture-





binding capacity, such food additives are used to stabilize the emulsion in the production of products from both red and white meat. The use of food additives containing phosphates allows [3–5]:

- preserve the natural properties of the product;
- avoid loss of product weight during defrosting, heat treatment and storage;
- improve the texture of products, give them juiciness and a delicate consistency;
- slow down oxidation processes during processing and storage;
- prevent the formation of rotten odor in poultry products.

A brief description of the most popular food additives containing phosphates is presented in Table 1 [6, 7].

Table 1

## Characteristics of food additives containing phosphates

Name of food additive	Description	Compound	Appearance
Doctoral Complement	Recommended for use in the production of cooked sausages	Stabilizer E450, acidity regulator E451, dextrose, table salt, flavor enhancer E621, antioxidant E316, extracts of natural spices and herbs	
Dairy Complement	Recommended for use in the production of boiled, semi-smoked, boiled-smoked meat products	Stabilizers E450, E452, acidity regulator E451, dextrose, table salt, flavor enhancer E621, antioxidant E316, natural spices and herbs, extracts of natural spices and herbs	
Walnut Complement	Recommended for use in the production of semi-smoked and cooked-smoked sausages, imparts a nutty flavor and aroma	Stabilizer E450, acidity regulators E451, E575, table salt, glucose, flavor enhancer E621, spices (black pepper, white pepper), antioxidant E316, flavorings, spice extracts	
Hunting Combi	Recommended for use in the production of boiled-smoked and semi-smoked sausages	Stabilizer E450, acidity regulator E451, sucrose, antioxidant E316, spices (coriander, cumin, garlic, ginger, allspice, black pepper, cloves), salt, spice extracts	

In addition to the positive effect, phosphates can have a negative impact on the quality of meat products and the health of their consumers. Thus, with an excess of phosphate-based additives introduced into meat products, an excessive increase in the pH value may occur, and, as a result, the product acquires an unpleasant taste and becomes tough. To minimize this effect, mixtures consisting of alkaline, neutral and acidic phosphates are used, ensuring that the pH of sausages does not exceed the pH value of 6.5 [8, 9]. The negative impact on consumer health is due to the fact that meatraw materials contain a sufficient amount of natural phosphate (up to 0.5% in terms of  $P_2O_5$ ), and additional addition of phosphates can lead to a significant imbalance in the calcium to phosphorus ratio towards the latter. In turn, excessive amounts of phosphorus are fraught with

calcium leaching from the body, which contributes to the development of osteoporosis, a metabolic bone disease characterized by a decrease in bone density as a result of a decrease in the amount of bone substance or insufficient calcification. In addition, phosphates in large quantities cause disorders in the cardiovascular system [10, 11]. Therefore, the content of phosphates in meat products is regulated by law [12] (Table 2) and is controlled by the manufacturer of the product during production control, as well as by independent accredited testing laboratories to confirm the compliance of meat products with added phosphates with current technical requirements, including within the framework of state control over compliance with technical legislation.

Table 2

**Safety indicators of food additives containing phosphates [12]**

Index and name of the additive group	Name of additives	Technological functions	Content of the main substance
E450 Pyrophosphates	Sodium dihydrogen pyrophosphate (i)	–	95 %
	Sodium monohydrogen pyrophosphate (ii)		95 % on an anhydrous basis
	Sodium pyrophosphate (iii)		95 % based on ignition
	Potassium dihydrogen pyrophosphate (iv)		–
	Potassium pyrophosphate (v)		95 % based on ignition
	Calcium pyrophosphate (vi)		96 %
	Calcium dihydrogen pyrophosphate (vii)		95 % on an anhydrous basis
E451 Triphosphates	Sodium triphosphate (5-substituted) (i)	Acidity regulators	85 % on an anhydrous basis
	Potassium triphosphate (5-substituted) (i)		85 % on an anhydrous basis
E452 Polyphosphates	Sodium polyphosphate (i)	Emulsifiers, stabilizers, humectants	P <sub>2</sub> O <sub>5</sub> content not less than 60 % and not more than 71 % based on ignition
	Potassium polyphosphate (ii)		P <sub>2</sub> O <sub>5</sub> content not less than 53.5 % and not more than 61.5 % based on ignition
	Sodium-Calcium polyphosphate (iii)		P <sub>2</sub> O <sub>5</sub> content not less than 61 % and not more than 69 %
	Calcium polyphosphates (iv)		P <sub>2</sub> O <sub>5</sub> content not less than 71 % and not more than 73 %
	Ammonium polyphosphates (v)		P <sub>2</sub> O <sub>5</sub> content not less than 55 % and not more than 75 % based on ignition

Currently, there are four standards in force in Belarus, the object of standardization of which is the

method for determining total phosphorus in food products (Table 3).

Table 3

**Brief description of standards for the determination of total phosphorus in food products**

Designation and name	Scope of application	The essence of the method of determination
GOST R 51482-99 (ISO 13730-96) Meat and meat products. Spectrophotometric method for determination of mass fraction of total phosphorus [13]	For all types of meat, including poultry, meat and meat-containing products (sausages, meat products, semi-finished products, culinary products, canned goods)	On the mineralization of the sample, the reaction of phosphorus with ammonium monovanadate and ammonium heptamolybdate with the formation of a yellow compound and photometric measurement of optical density at a wavelength of 430 nm
GOST 30615-99 Stuff and food products. Method of determination of phosphorus [14]	For raw materials and food products	The method consists of dry mineralization of the sample, dissolution of the ash, carrying out a color reaction with a molybdenum-vanadium reagent and measuring the intensity of the yellow coloration of the solution $\lambda = (440 \pm 5)$ nm using a photoelectrocolorimeter or spectrophotometer
GOST 32009-2013 (ISO 32009:1996, MOD) Meat and meat products. Spectrophotometric method for determining the mass fraction of total phosphorus [15]	For all types of meat, including poultry, meat and meat-containing products (sausages, meat products, semi-finished products, culinary products, canned goods)	The method is based on drying the sample, ashing the precipitate with subsequent cooling and hydrolysis of the ash with nitric acid, filtration, dilution of the filtrate with a mixture of ammonium monovanadate and ammonium heptamolybdate to form a yellow compound and photometric measurement of the optical density at a wavelength of 430 nm
GOST 9794-2015 Meat products. Methods	For all types of meat, including poultry,	Gravimetric method: mineralization of the sample with nitric and sulfuric acids, precipitation of

for the determination of total phosphorus content [16]	meat and meat-containing products	phosphorus in the form of quinoline phosphomolybdate and determination of the mass of the precipitate after filtration. Spectrophotometric method: reaction of phosphorus with ammonium molybdate in the presence of hydroquinone and sodium sulfite to form a colored compound and photometric determination of optical density at a wavelength of 630 nm.
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An analysis of the essence of standardized methods for measuring total phosphorus showed that the basis for determining this indicator is the mineralization of the sample, obtaining a colored compound and determining its optical density with subsequent calculation of total phosphorus using a calibration curve. An exception is the gravimetric method for determining total phosphorus (GOST 9794-2015). It should also be noted that the methods considered are applied, for the most part, to meat and meat products, and only in one standard (GOST 30615-99) – to raw materials and food products. There is no indication that the specified measurement methods can be applied to complex food additives containing phosphates. However, manufacturers of

food additives with phosphates indicate the content of total phosphorus in terms of  $P_2O_5$  in quality (origin) certificates without reference to the determination method used. In this regard, it was of interest to adapt one of the current methods for determining total phosphorus in meat products to measure this indicator in complex food additives with phosphates for meat products, which was the purpose of this work.

**Materials and methods.** The objects of the study were 5 samples of complex food additives for meat products containing phosphates, kindly provided to us for the study by one of the meat processing plants in Belarus. A brief description of the objects of the study is given in Table 4.

Table 4

#### Characteristics of research objects

Item No.	Research object	Compound
1	Boiled creamy combi	Flavor enhancers: monosodium glutamate E621 (30 %), di-sodium 5'-ribonucleotides E635 (0.4 %), dextrose, stabilizers: pyrophosphate E450, polyphosphate E452, acidity regulator: triphosphate E451 ( $P_2O_5$ content: 13 %), dry cream, antioxidant: ascorbic acid E300, broth (iodized salt (salt, potassium iodate), sugar, yeast extract, maltodextrin, sunflower oil, spices), flavoring (butter), vegetable hydrolysate
2	Grillfix 20 grilled meat	Table salt, spices (garlic, coriander, cumin, marjoram, nutmeg, paprika, black pepper, onion), spice extracts (paprika, rosemary), dextrose, acidity regulator: sodium acetate E262, stabilizers: sodium citrate E331, pyrophosphates E450, acidity regulator: triphosphate E451 ( $P_2O_5$ content: 3 %), flavor enhancer: monosodium glutamate E621 (6 %), antioxidant: ascorbic acid E300, sodium ascorbate E301
3	Citrim 43	Acidity regulators (E332, E451), dextrose
4	Viennese combi	Table salt, acidity regulator (E450i), stabilizer (E451i), flavor enhancer (E621) 16.7 %, antioxidant (E316) 3.3 %, spice extracts
5	Profix 45	Acidity regulator E451i, stabilizer E450i

The subject of the study is phosphates in complex food additives in terms of  $P_2O_5$ . The research method is spectrophotometric according to GOST R 51482-99 (ISO 13730-96) [13]. The determination of total phosphorus included the following stages:

- selection of 2.0 g samples;
- ashing of the samples in a muffle furnace at a temperature of 250 to 550 °C in 50 °C increments. The appearance of the resulting ash is shown in Figure 1;
- preparation of ammonium monovanadate and ammonium heptamolybdate solutions;
- preparation of a coloring reagent;
- preparation of standard and calibration solutions of phosphate (Figure 2). The resulting calibration solutions contained 50, 100, 150, 200, 250, 300  $\mu\text{g}/\text{cm}^3$   $P_2O_5$ , respectively;

- measurement of the optical density of the calibration solutions relative to the control solution and construction of a calibration graph;
- dissolution of ashed samples and preparation of solutions for measuring optical density;
- measurement of optical density of solutions and determination of total phosphorus concentration in terms of  $P_2O_5$  using a calibration graph;
- determination of the mass fraction of total phosphorus in samples of complex food additives;
- processing of the obtained results.

Measurement of optical density of calibration and test solutions was carried out in two parallels on a Cary 50 spectrophotometer at a wavelength of  $(440 \pm 5)$  nm with CaryWinUV software.



Fig. 1 – Appearance of the objects of study after ashing



Fig. 2 – Calibration solutions

The mass fraction of total phosphorus  $X$ , % (in terms of  $P_2O_5$ ) was determined by the formula:

$$X = \frac{C}{10 \cdot m} \quad (1)$$

where:  $C$  – mass concentration of phosphorus pentoxide found from the calibration graph,  $\mu\text{g}/\text{cm}^3$ ;

$m$  – sample weight, g.

**Results and discussion.** The calibration graph, constructed based on the results of measuring the optical density of calibration solutions, is shown in Figure 3.

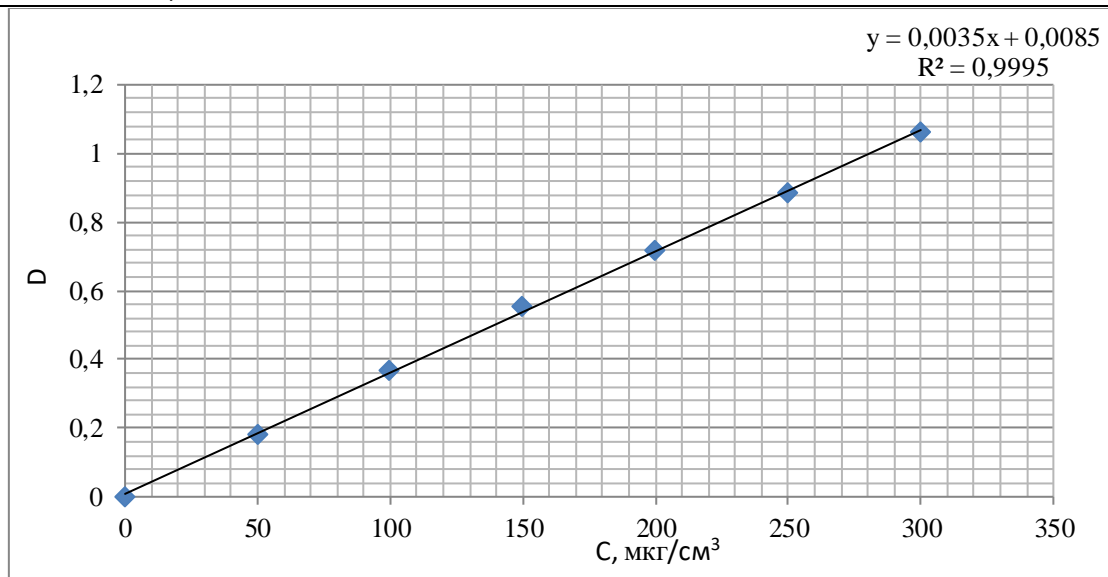


Fig. 3 – Calibration graph

As can be seen from graph 3, the dependence  $D = f(C)$  has a linear form. The points are located on the line, which indicates that the measurements were carried out correctly and there are no errors. The results of

measuring the optical density of the experimental solutions and determining the mass concentration of total phosphorus according to the calibration graph are presented in Table 5.

Table 5

**Results of measuring the optical density of experimental solutions and determining the mass concentration of total phosphorus using a calibration graph**

Number and name of the complex food additive	Average optical density value $\langle D \rangle$	Average value of mass concentration of total phosphorus, $\mu\text{g}/\text{cm}^3$
1 Boiled creamy combi	0,919	260,09
2 Grillfix 20 grilled meat	0,218	60,04
3 Citrim 43	0,919	260,01
4 Viennese combi	0,709	200,04
5 Profix 45	4,001	1140,18

The results of calculating the mass fraction of total phosphorus in terms of  $\text{P}_2\text{O}_5$  in the studied samples are presented in Table 6.

Table 6

**Results of calculation of the mass fraction of total phosphorus in terms of  $\text{P}_2\text{O}_5$  in the objects of study**

Name of the complex food additive	Average value of mass fraction of total phosphorus, %	The value specified in the specification, %
1	2	3
Boiled creamy combi	13,0001	13,0
Grillfix 20 grilled meat	3,0002	3,0
Citrim 43	13,0000	13,0

**Continuation of table 6**

1	2	3
Viennese combi	10,0000	10,0
Profix 45	57,0002	58,0

As can be seen from the data presented in Table 6, the values of the mass fraction of total phosphorus in the studied samples of complex food additives correspond to the values established in the specifications for the objects of study.

**Conclusions.** Based on the analysis of the obtained results of our experimental study, we can make a preliminary conclusion that the method for determining

total phosphorus by the spectrophotometric method according to GOST R 51482-99 (ISO 13730-96) can be extended to complex food additives with phosphates. To expand the scope of application of the standardized measurement method we used, additional validation studies are required to establish its metrological characteristics.

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